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MAN, SCIENCE, AND THE SPACE PROGRAM

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Introduction

Man's intellectual growth has been paced by his conquest of natural frontiers. Nineteen hundred and sixty one, the year of man's first direct penetration of the space frontier, will rank in history with 1492, 1913, and 1927.

The first feeble excursions into space are already giving shape to major changes in technology. World communication systems based on satellite relay stations (Figure 1) are already in the process of implementation. These space flight systems will first greatly expand the capability of our present world communication networks. Later, direct world-wide availability of televised information will drastically expand our potential for the spread of knowledge.

Meteorological satellites have been put to work in the study of gross weather effects. Practical hurricane warning techniques have already been demonstrated.

The telephone, the automobile, and the airplane have had major effects on evolution of our social structure. The applications of technology from the Space Age can serve as an even greater catalyst to the evolution of sociology.

The exploration of space requires radical extension of the inherent perceptual and physical capabilities of man. All human knowledge is the result of information integrated with the human intellect. Man's early learning was limited by the perceptual band width of his unaided senses. Figure 2 shows the very small parts of the electromagnetic and sound spectra directly usable by unaided human vision and hearing. His activities were restricted by his own physical limitations.

The rapid development of vehicle and scientific equipment has given rise to much discussion as to whether space can be explored best by men or by remotely controlled, instrument-carrying vehicles. The proponents of one side or the other of this argument sometime tend to overlook some simple facts behind the argument:

(1) Without the use of machines to extend his perception and mobility, man is limited to observations he can make directly from his own position on the Earth.

(2) Machines are only useful to the extent that they gather information for, be controlled by, or otherwise perform in response to man's desires.

There is, then, no such thing as an "unmanned space flight experiment". The important question is: "Where and in what capacity can men and machines best be employed to contribute to the overall effectiveness of each flight system or experiment?" Two considerations are fundamental to the resolution of this question.

(1) To become useful knowledge, information gathered must be made available to human intellect.

(2) Distance, intervening atmospheres and other matter ranging from space dust particles to planets, fundamentally attenuate the availability of information transmitted through space. If the amount of detailed information required per unit time is large, then it is necessary that a human be correspondingly closer to the source of information. Where the desired amount of information is small or the time for acquisition can be long, the remotely activated instruments tend to be economical. If it is necessary to take action on or interact with an experiment at great distance, it must be remembered that a time lag associated with the speed of light is inherent.

For example, the round trip time for a signal from the Earth to the Moon is 2.6 seconds, from Earth to Venus, 356 seconds.

Propulsion has long been the limiting technology in space flight. In a practical sense, of course, propulsion will remain for some time as a limiting technology. Research progress, on the other hand, is illuminating potential methods for carrying large payloads great distances. The research problem most critical now appears to be the improvement in linkage of information to the human intellect. Little of value will be gained from highly sophisticated space vehicle systems unless balanced progress is made in making the information gathered available to and understandable by the scientific investigators.

As an example of the need to improve the form of the data received, Figure 3 is a sample of graphical data received from radiation measuring equipment aboard a satellite vehicle. It is extremely time consuming and difficult for even the best trained scientist to assimilate and interpret these data. On the other hand, a pictorial presentation of the relationship of the Van Allen radiation region to the Earth (Figure 4) can convey a great deal of information to even an untrained individual.

Research and development to expand the utility of such concepts by the use of advance data sensing, computing, and display techniques shows great promise of accelerating the rate at which data can be gathered and displayed in a manner conducive to rapid assimilation as human knowledge.

The effective and timely exploration of space will make use of both remotely-controlled and directly-manned vehicles. The instruments of satellites and space probes can perform intricate tasks of sensing and measuring. They can perform only as they are programmed, however, since they lack the flexibility to take new courses of action as a result of unexpected information. Scientific data from these devices will be effectively supplemented by "on the spot" human senses, reasoning, and judgment.

Data from the rapidly expanding space flight programs are already stimulating evolution in a concept of the solar system.

Efforts of scientists of varied disciplinary backgrounds are utilized in the space program. The efforts cut across the disciplines of astronomy, physics and the Earth sciences. It involves close interactions among experts in both the physical and the life sciences. The exchange of ideas among scientists of many different backgrounds has in itself stimulated the evolution of knowledge. Information gathered from space has provided an additional impetus to scientific inquiry on the nature of the environment of our solar system.

Dr. Robert Jastrow, Director of the NASA Space Science Institute, has summarized activities on the exploration of the solar system as follows:

" The studies are concerned with the manner in which the sun controls the atmosphere of the Earth; to the structure of the Earth; the moon and other bodies in the solar system; to the origin and history of the solar system; and to the structure and evolution of the stars and galaxies. The scientists who work together on these investigations are united by their common interest in the World around them--the Earth, its atmospheres, the solar system, the stars and galaxies. This new composite emphasis on the exploration of our environment has created great activity. In 1960 alone, 120 articles on space research were published in the Journal of Geophysical Research."

The tools of this effort include sounding rockets, satellites, deep space probes, and vehicles for landings on the moon and the planets. Eventually bases on the moon and the planets will serve as observation outposts for extension of the exploration of space.

The NASA program includes effort in the following major areas: (Figure 5) (1) Space Sciences; (2) Applications of the results of space programs to general use; (3) Manned Space Flight; (4) Advanced Research and Technology; and (5) Tracking and Data Acquisition.

The effort in the Space Sciences emphasizes work in the areas noted in Figure 6. This program is designed to provide scientific data needed to better understand the world and the universe. It provides technology important to national growth and scientific data pertinent to manned space flight and the space applications programs.

The scientific satellite and sounding rocket program is illustrated in Figure 7. This program is being developed to obtain through the use of geophysical observatories, sounding rockets, solar observatories, and astronomical observatories, a more detailed knowledge of: the Earth as a planet, including its atmospheric properties; the sun and its effects on the Earth; and the stars and galaxies. Many projects are in process to achieve these objectives.

Geophysical data (magnetic fields, gravity fields, radiation belts) will be obtained from satellites known as geophysical observatories. Flights of large observatories, the Eccentric Orbiting Geophysical Observatory and Polar Orbiting Geophysical Observatory, will be made in the 1963 through 1964 time period. Sounding rockets have played and will continue to play an important role in this program.

Atmospheric data and energetic particles data (studies of the upper ionosphere, the upper atmosphere, radio wave propagation, and space environment) will be obtained from sounding rockets and satellites with flights programmed on a continuing basis during 1962 and 1963. Several of the satellites to be flown in this program represent cooperative projects with other countries, notably Canada and the United Kingdom. Generally, NASA provides the spacecraft and launch vehicle, and they provide instrumentation for the experiment.

The Orbiting Solar Observatory Program is designed to give a better knowledge, on a continuous basis, of the unsteady solar electromagnetic activity. In this program, four flights are planned for the 1962 and 1963 period.

Knowledge of the stars and galaxies will be obtained from the Orbiting Astronomical Observatory. In this program much of the astronomical work will be done in the ultraviolet light regime, where observations from Earth are not possible due to the absorption of ultraviolet light in the Earth's atmosphere. Present development indicates that these observatories will be flown in late 1963 and 1964.

Figure 8 illustrates the Unmanned Lunar Exploration Program. The objectives of the presently planned program are an initial determination of the physical characteristics of the moon and earth-moon environment.

The first lunar flights are to be accomplished with the Ranger spacecraft in the 1962-1963 period. This spacecraft, weighing about 750 pounds, is designed to land a small capsule on a lunar surface. As the moon is approached by the spacecraft, TV pictures will be taken of the lunar surface and transmitted to Earth. The capsule, after impacting the moon, will transmit lunar seismic data to Earth for the life-time of the instrument package, estimated to be about one month.

Nine spacecraft are in this program. Two development flights have been attempted; neither launch was successful due to failures in the launch vehicles. The Rangers were injected into low earth orbits and not into the highly elliptical orbits desired. However, during the short flights, the Ranger spacecraft appeared to perform satisfactorily.

The first Ranger flight to the moon did not result in a lunar impact. Due to excessive velocity, the Ranger flew past the moon. However, the spacecraft and command control systems worked fairly well.

The Ranger Project will be followed by the Surveyor Project. This project has two major objectives: soft landing about 350 pounds of instruments on the visible side of the moon for detailed studies of lunar surface characteristics and measurements of the lunar environment; and orbital flights for extensive mapping of the lunar surface. Flights will start in 1963, and plans call for them to continue through 1965.

The mapping operation is a new mission. It was developed to assist in the selection of landing sites for the Manned Lunar Landing Program. The project will also provide significant scientific information, and may yield a long-life satellite of the moon to monitor radiation and other environmental and geophysical parameters.

The Prospector Project, which may follow the Surveyor, is illustrated on the right of this Figure. At present it appears that the Prospector would be used for transporting significant payloads to the lunar surface in support of unmanned scientific lunar exploration and manned lunar operations. The present effort is essentially limited to in-house study. In fiscal year 1963 more detailed study of the role of the Prospector will be undertaken on contract to develop concepts, design specifications, and preliminary designs.

Figure 9 illustrates the planetary exploration program. This program is designed to determine, in a preliminary fashion, the physical characteristics of the near planets, Venus and Mars, explore the related interplanetary space environment, obtain measurement of solar characteristics, and search for extraterrestrial life.

The program consists of a Venus fly-by in 1962 with the Mariner R spacecraft. This spacecraft is a modified Ranger. It will be launched by an Atlas-Agena B.

The Mariner R program will be followed by the Mariner B flights to Venus and Mars in March and November of 1964, respectively. The Mariner B's will be launched by the Centaur. A test of the Mariner B spacecraft, on an escape mission, will be made in 1963.

Follow-on planning calls for the Voyager spacecraft to orbit Mars and Venus, and launch probes to the surface of these planets, some time after 1965.

The Mariner R will fly by Venus and will obtain limited information on magnetic fields, atmospheric properties and surface temperature distribution. On the way to the planet, interplanetary environmental data will be obtained.

The Mariner B, being about twice the size of Mariner R, will allow more complete instrumentation. A small planet probe may be included for the Mars mission. The probe would enter the atmosphere of Mars and relay atmospheric and planetary data to Earth through the parent spacecraft.

The Voyager is under study for both Mars and Venus missions. It is anticipated that it would weigh about 1,500 pounds and require a Saturn launch vehicle. Whereas the Mariner R and Mariner B spacecraft fly by the near planets, the Voyager may orbit these planets. Detailed planetary information would be obtained from a capsule released from the Voyager and designed to penetrate the planetary atmosphere and land. As in the Mariner B capsule, data would be relayed to Earth through the parent spacecraft. The efforts on Voyager, this coming fiscal year, will be limited to detailed design studies.

The light and medium launch vehicles that support these and other NASA missions are illustrated on Figure 10. These vehicles are part of the National Launch Vehicle Program and are the responsibility of the Office of Space Sciences. They provide the capability of putting from 150 pounds to 8,500 pounds in about a 350-mile orbit.

All of the vehicles, with the exception of Scout and Centaur, have completed their development programs. Scout is essentially through initial development. However, a program is underway to increase its payload from 150 pounds to about 240 pounds and to provide greater injection accuracy. The improved vehicle should be available in 1963.

The Centaur launch vehicle is about ready for its first flight test. This vehicle consists of a modified Atlas first stage and a second stage powered by two RL-10, 15,000 pound thrust, engines that utilize liquid hydrogen and liquid oxygen as propellants. This will be the first flight test of a stage powered by these higher energy propellants. Development flights will continue through 1963. The vehicle should be operational by 1964. The Centaur design and operational experience will be of significant value in the development of the liquid hydrogen and liquid oxygen powered upper stages of the large launch vehicles.

Specifically, these vehicles will be utilized as follows:

Scout will be used extensively in the Space Science Programs for launching probes and satellites for atmospheric, energetic particles, and space radiation measurements. The vehicle is to be utilized also in research programs for the study of problems related to spacecraft atmosphere reentry and electric propulsion. The Department of Defense also has extensive plans for the use of this launch vehicle.

The Delta launch vehicle is heavily programmed for space science satellites. It will be used also by the applications program for launching meteorological satellites and active communications satellites.

The Thor-Agena B will be used to launch satellites that study the upper ionosphere, advanced meteorological satellites, geophysical satellites, and communications satellites.

The Atlas-Agena B will launch the advanced geophysical satellites, the Orbiting Astronomical Observatories, the Rangers, and advanced communications satellites.

Centaur will be used in NASA's lunar and planetary programs and by the Department of Defense for communications satellites.

The Applications Program at the present time has major activities in Meteorology and Communications. (Figure 11) In addition, satellite applications such as will be used eventually to support other services are being considered. A study of navigational systems for ships and aircraft will be coordinated with the Department of Defense, the Maritime Commission, the Federal Aviation Agency, and the U. S. Coast Guard.

The meteorological program is outlined on Figure 12. It consists of three projects, Tiros, Nimbus and Aeros - satellite systems that will progressively improve the monitoring and prediction of world-wide weather conditions and the understanding of meteorological activity. At present the satellites provide meteorological observations through the acquisition of the following kinds of information: cloud cover, storm locations, temperature and heat balance. The programs are concerned not only with the spacecraft but with the on-board equipment required to obtain these data, the data handling equipment and the satellite-to-earth communication systems required.

The Tiros program has been publicized extensively. The first Tiros satellite was launched in 1960 and operated continuously for a period of about three months. It demonstrated the usefulness of satellites for weather forecasting and provided a great quantity of data. These data continue to be of use to the Weather Bureau, universities and other research groups for theoretical investigation of weather dynamics.

Tiros I was followed by Tiros II in November, 1960, and Tiros III in July 1961, and the very recent flight of Tiros IV in February, 1962. Tiros II and III were reasonably successful and provided much useful data. Some systems on Tiros II remained in operation for almost a year. Thus far, Tiros IV has proven very successful. Three more Tiros flights are scheduled in 1962 and will overlap the follow-on Nimbus program.

The Tiros satellite is spin stabilized and as shown on Figure 12, its cameras can look at the Earth for only a certain portion of each orbit. Its picture taking is limited to the times the cameras look at the Earth and the Earth is in sunlight.

The Nimbus satellite, which should have its first flight in 1962, is more versatile. Nimbus, as shown on Figure 12, has a control system that keeps its cameras looking continuously at the Earth within an angle of about 1^{o} of the local vertical. The cameras will be of higher resolution than those in Tiros. Night cloud cover information will be obtained through the use of infrared radiation sensors.

The Nimbus program is an effort supported jointly by the NASA and the Department of Commerce through the United States Weather Bureau. The program consists of eight satellites, four for research and development, and four for initial exploration of operational utilization.

The Weather Bureau carries responsibility for establishing the meteorological instrumentation requirements, meteorological data processing and analysis, and data utilization for these programs. The NASA is responsible for the spacecraft including its sensors, launch operations and tracking. The NASA is responsible also for the programming of commands to the satellite and acquiring the data.

Beyond Nimbus is Aeros, a study program. Aeros is conceived as a meteorological satellite system of three or four units placed symmetrically about the equator in a "stationary" (24-hour) orbit, thus allowing full-time weather coverage. One such satellite is illustrated on Figure 12. The satellite would be equipped with two cameras. One covers the globe. The other, in response to commands from the Earth, would look at selected areas of the Earth for detailed study of weather conditions. Investigations of instrumentation for Aeros will begin the early part of this year.

Figure 13 illustrates the Communication Satellite program. This program consists of two passive communications satellite projects, Rigid Echo and Rebound, and a number of active repeater systems, Relay, Telstar and Syncom. It is the objective of this program to provide a rapid and continuous increase in scientific and technological knowledge pertinent to early establishment of global communications satellite systems for civil use.

Echo I, the 100-foot inflated sphere for communications experiments, was launched August 12, 1960, and was a completely successful operation. The satellite, still circling the globe, proved the usefulness of a light-weight inflatable satellite for passive communications. The program is being extended through the use of rigidized inflatable spheres of a larger size. The increase in size is to increase the strength of the reflected signal and the rigidization is to extend the useful life time of the sphere for communications purposes. In a recent suborbital flight, the sphere was ripped during the inflation process. Another development shot will be made soon. The Rigid Echo satellite will fly in 1962 in about a 650-mile high orbit.

Project Rebound will follow in 1963 making use of Echo II satellite technology. Rebound has two objectives: 1) development of a multiple satellite launch from a single launch vehicle and spacecraft; and 2) study the usefulness of rigidized spheres for passive continuous communications. The communications system will consist of three satellites carefully spaced around the Earth at an orbital altitude of about 1700 miles. The Department of Defense will participate in this experiment.

The first active communications satellite launched by the NASA will be Telstar, a private venture funded by the American Telephone and Telegraph Company. Two launchings of Telstar, designed to fly in an elliptical orbit to an altitude of about 5,000 miles, are scheduled in 1962. The NASA, to be reimbursed for its costs, is responsible for launch vehicle procurement, and launch operations. The NASA is responsible also for tracking the satellite and for some ground station, data processing and data analysis operations. Telstar will be capable of handling television transmission. Initially it is anticipated that joint experiments will be conducted with France and England. At a later date Germany will participate in the program.

Data obtained in this program will be made available to others interested in satellite communications systems.

Relay is another medium altitude active communication satellite experiment. It will be flown during 1962 and 1963. This satellite, weighing about 125 pounds, is spin stabilized. It will accommodate (wideband) communications corresponding to about one channel of television. As illustrated, Relay will fly an elliptical orbit reaching an altitude of about 3,000 miles. The experiment will be a joint one involving the United States, Great Britain, France, Germany and Brazil.

The Syncom satellite shown on Figure 13 is an active repeater (narrowband) system stationed in a 24-hour orbit thus keeping constantly in the sight of one segment of the Earth. About 28 inches in diameter and about 125 pounds in weight, it will be available for launching in late 1962. Seventy pounds of this weight is associated with the rocket that will inject the spacecraft into the 24-hour orbit. The spacecraft will have attitude and position controls and be capable of handling one full duplex radio telephone channel.

Syncom is a cooperative program with the Department of Defense. They are providing transportable ground stations for the communications experiment.

In addition to these on-going flight programs, studies are underway to modify the Relay satellite into a stabilized active repeater satellite that would orbit at altitudes between 6,000 and 10,000 miles. This would provide fairly long duration visibility between countries and represents a compromise between satellites in low orbits, and the 24-hour "stationary" satellite. The low orbit system requires many spacecraft. The stationary system requires complex launch operations and the spacecraft life expectancy may be short.

An extension of the Syncom program is also being considered. The new satellite would have an increased number of channels and could permit television transmission.

The Manned Space Flight program has increased considerably since the President and the Congress established manned landing on the moon and return to Earth as a National objective. The program now includes projects aimed at the accomplishments noted on Figure 14; earth orbital flights from 3 orbits to one week in duration; rendezvous in earth orbit; circumlunar flight; and lunar landing and return. In addition the program includes development of launch vehicles and support facilities.

Studies show that if the spacecraft that returns to the Earth with the astronauts weighs 12,000 pounds, a spacecraft system weighing about 60,000 pounds must land on the moon. In turn this requires a spacecraft weight approaching 400,000 pounds in a 300-mile earth orbit. A single launch vehicle placing this weight in orbit would have to produce about 12,000,000 pounds of thrust. This is ten times greater than anything flown and represents a major launch vehicle development.

However, if rendezvous in space is used, the lunar mission can be carried out using lower thrust launch vehicles. For example, if one assembly operation in orbit were utilized, a launch vehicle with a lift-off thrust of about 6,000,000 pounds could satisfy the launch requirements.

Decisions have been made to develop launch vehicles in both of these thrust classes. Thus, the large launch vehicle program includes the familiar Saturn C-1 and these new vehicles named Advanced Saturn and Nova. Figure 15 shows the Saturn C-1, the Advanced Saturn and the Nova. Shown also are the liquid rocket engines that power these vehicles.

The Saturn C-1 will launch into sub-orbital and orbital flight the spacecraft being developed for the manned lunar landing. It has eight 188,000 pound thrust liquid-oxygen, kerosene H-1 engines in the first stage. The second stage employs six 15,000 pound thrust liquid-oxygen, liquid-hydrogen A-3 engines. As you know, the first stage had a very successful flight the end of the past year.

The Advanced Saturn will be utilized in the circumlunar mission and with rendezvous in the lunar landing mission. The vehicle has five 1-1/2 million pound thrust liquid-oxygen, kerosene F-1 engines in the first stage. This engine has been under development for 3 years and will be proof tested in 1963. The second stage utilizes five 200,000 pound thrust liquid-hydrogen, liquid-oxygen J-2 engines and the third stage utilizes one J-2 engine. This engine has been under development for a little over a year and will be proof tested in 1963.

The Nova vehicle will be capable of providing direct manned flights to the moon and return to the earth and will be utilized for more extensive exploration of the near planets and space. This vehicle will have eight 1-1/2 million pound thrust liquid-oxygen kerosene F-1 engines in the first stage, four 1 million pound thrust liquid-oxygen, liquid-hydrogen M-1 engines in the second stage and a single J-2 engine in the third stage.

You will note that NASA launch vehicle plans for manned missions do not include the use of large solid rockets. This does not rule out, however, the possibility that these rockets will be of interest in the future. NASA is in close contact with the Department of Defense on their developments of large solid rocket motors. The results of these developments will be used where required in the NASA program.

Figure 16 is an illustration of the familiar Mercury spacecraft. The Mercury project was designed to provide flights of up to three orbits, a duration of 4-1/2 hours. It is the broad purpose of the project to study the effects of space flight on man, including his ability to perform useful functions, and to develop the technology required for further manned exploration in space. This past year has seen the successful sub-orbital flights of Allan Shepard and Virgil

Grissom, and the orbital flight of the chimpanzee, Enos. This year has already seen the successful full duration flight of John Glenn, Jr. Four more flights are planned in this program. It is anticipated that they will be maximum duration flights and should be completed by the end of the year.

Modifications to the basic Mercury spacecraft are in progress. These modifications include increasing the capacity of the battery system, the attitude control system, and the life support system. This will allow orbital flights of up to one day. Figure 17 depicts the 1-day manned flight spacecraft, a Mercury with an enlarged service pod for the equipment just mentioned. The flight program planned will begin in late 1962 and extend into early 1963. It is the purpose of the program to increase the operating time of equipment in space, and in particular to determine man's physiological and mental response to the prolonged zero-gravity experience. From this program NASA will move to a larger spacecraft capable of more extensive space flight operation, Project Gemini.

Project Gemini is illustrated in Figure 18. Depicted is a two-man spacecraft about to complete a rendezvous maneuver with an Agena-B propulsion stage. Project Gemini has three major objectives: operational experience with two men; long duration orbital flights of up to one week; and the attainment of rendezvous technology and operational experience. The spacecraft will also allow early tests of advanced spacecraft (Apollo) components and systems. The flight program will be initiated in 1963.

Briefly, a rendezvous operation will consist of placing the modified Agena-B in orbit. This will be accomplished by an Atlas. When the Agena-B orbital conditions are determined and a check made to see that the Agena-B is operational, the manned spacecraft will be launched. This will be done by a Titan II. Launch timing and mid-course correction will be such that the manned spacecraft will be placed in close proximity to the Agena-B propulsion stage. The astronauts will then control the Gemini spacecraft in the approach maneuver and into a terminal coupling with the Agena-B.

The Gemini project is considered particularly important to manned space flight. As already indicated, rendezvous is the technique that will be emphasized for accomplishment of a manned lunar landing and Earth return. For this mission the manned spacecraft and the lunar propulsion modules would be mated to the earth escape rocket in an earth orbit. After system checkout, the launch from earth orbit to the moon would be made.

The rendezvous technique has other potential uses such as supply, crew transfer, maintenance and rescue, and is of great interest to the Department of Defense.

Let us now direct attention to the Apollo program, the program for taking man to the moon and returning him safely to Earth.

The missions making up the Apollo program are illustrated in Figure 19. These missions are flight in earth orbit, circumlunar flight, and lunar landing and return.

Earth orbital flights for spacecraft development should start in 1964. Lunar circumnavigation flights to further develop the spacecraft and provide operational experience are projected for the 1966 time period. This will be followed by lunar landing and return before 1970.

It is anticipated that early in this program a simple manned orbiting laboratory will be developed for the general scientific and technological studies that can be conducted only in space.

To support the national programs in space and aeronautics, a substantial research and advanced technology effort is required. The program supported by the NASA is outlined in Figure 20. Involved are studies and developments in the areas of aircraft and missiles, spacecraft, launch vehicles including launch operations, nuclear systems, space power systems, and propulsion.

The scope of the aircraft and missile technology effort is illustrated on Figure 21. The program encompasses slow-speed aircraft, helicopters and VTOL/STOL airplanes; supersonic transports; tactical aircraft; hypersonic aircraft, as symbolized here by the X-15 and a hypersonic glider; and missiles.

The vertical take-off and landing and short take-off and landing airplane program includes not only analytical and wind tunnel work but a substantial flight research effort.

The supersonic transport effort has been and will continue to be the largest effort in aircraft research and technology. There is close cooperation with the Federal Aviation Agency and the Department of Defense on the development of supersonic transport design concepts. The NASA is providing also basic engineering information on structures, aerodynamics, propulsion, and flight control for speeds from landing to 2,000 miles per hour.

The tactical airplane studies are in direct support of the Department of Defense and the NATO countries. Configurations designed to fly efficiently at extremely high speeds at low altitudes for close-in support of ground troops are being developed.

In the hypersonic aircraft area the X-15 flight program represents the largest effort. This program, conducted jointly with the Department of Defense, has been highly successful. Over 45 flights have been made with the aircraft. It has flown through most of its critical design conditions providing much useful data on aerodynamic heating, structures, operating problems and flight control. Flight programs laid out for the X-15 airplanes will keep them active for several more years.

The NASA is also supporting the Air Force's Dyna-Soar project. The effort consists of generalized and specific studies to assist in the design and development of the Dyna-Soar spacecraft and its launch vehicle. The work also involves development of research instrumentation for the flight program.

The missile efforts of the NASA are relatively small but deal in several critical areas of direct interest to, and in support of the Department of Defense. Representative studies are: radar reflection of bodies reentering the atmosphere at hypersonic speed; aerodynamic interference and structural flutter; and dynamic interaction between missile structures, fuel, and guidance and control systems.

Figure 22 depicts the Spacecraft Technology activity. Involved are such matters as communications and handling of data from spacecraft reentering the Earth's atmosphere; reentry configurations; aerodynamic heating; and flight control.

In support of flights to the moon and planets, the program encompasses studies of lunar landing, planetary entry and systems for lunar and planetary guidance and navigation.

Special attention has been and will continued to be directed at problems of propulsion systems in space. Noted on the figure are some of the matters that are of concern: structures, micrometeoroid hazard, and propellant storage in the environment of space.

Support of this program requires not only ground based activity but also space flight experimentation. Flight experiments planned involve: reentry heating; heat shield materials; communication, horizon sensors, micrometeorite damage and protection; and reentry at the speeds of about 25,000 miles per hour, the speed associated with lunar return.

The launch vehicle technology effort is illustrated in Figure 23. This program is concerned with the guidance and control of large flexible launch vehicles, materials for their construction--particularly tankage, efficient structural design, problems associated with the clustering of many engines and, of course, the integration of all these systems into an efficient reliable launch vehicle.

In the past little attention has been directed to the operational support of launch vehicles. A considerable increase in this effort is planned in preparation for the large operations to be supported in the near future for scientific, applied and manned space flight programs. Problems of handling large liquid and solid propellant vehicles will be studies. Launch site operations, on-pad vehicle check and monitoring, and the launch operation are additional matters that will receive attention.

The program in nuclear system technology is represented pictorially on Figure 24. Attention has been directed to three major items; the nuclear rocket, nuclear electric power conversion systems, and the application of nuclear electric power systems to nuclear electric propulsion.

In these areas, the NASA is working jointly with the Atomic Energy Commission. The AEC carries the responsibility for reactor development. The NASA carries responsibility for complete power generation system and nuclear rocket system design and the integration of these systems with their respective nuclear reactor into the final light package.

The Nuclear Rocket Development program is made up of these programs: the KIWI reactor; the NERVA nuclear rocket engine; and a flight test program called RIFT. RIFT flights should take place later this decade.

The objective of the Nuclear Electric Power Conversion program is to develop for flight use a nuclear powered electrical generating system that can provide up to 60 KW of electrical energy for auxiliary power applications or for powering electric propulsion systems.

In addition to the reactor work being pursued by the AEC, NASA is developing the electric conversion system and combining these two elements into a power package called SNAP-8. SNAP-8 is being designed to provide 30 to 60 KW of electrical power. 30 KW power units will be ready for preliminary flight tests in the 1965-1966 time period. Long life ground tests, involving 10,000 hours of continuous running, should be completed in 1966-1967 at which time the SNAP-8 will be ready for long duration flight testing.

Study and experimental effort in this program area involves mechanical components such as: turbines, bearings and generators, radiators for dissipating excess heat, and power conversion systems. Increased attention is being given to systems that generate power levels approaching a million watts. This power level is required if practical application of electric propulsion to interplanetary flight is to be realized.

Nuclear electric power and battery systems do not satisfy all of the anticipated power requirements when vehicle and mission design limitations are taken into consideration. Studies of future power requirements and possible solutions have resulted in a number of other interesting power generating techniques that are being studied actively. These include systems that directly convert solar heat to electricity, solar heated boiler-turboelectric systems and high efficiency solar cells.

The Nuclear Electric Propulsion effort is directed at the study of systems and their components. Electric propulsion systems promise extremely high efficiency and would be used for such functions as trajectory correction in deep space flight, orbit transfer in close Earth flights, and power to shorten flight times on deep space missions. Present efforts include basic research, and development of a flight research program to establish the feasibility of electric propulsion. If results from battery powered flight tests and later flight tests with SNAP-8 powered engines prove the feasibility of electric propulsion, we will proceed with development of electric engines in the million watt size.

Figure 25 illustrates research effort for chemical rockets. The NASA is interested in liquid rockets and solid rockets. In the liquid rocket field, of primary concern are large thrust engines that utilize high energy fuels such as liquid hydrogen. Particular attention is being given to means for providing variable thrust, to restarting in space, and to engine components (propellant flow systems, pumps, turbines, controls, thrust chambers and nozzles).

Although the Department of Defense is supporting large solid rocket research and development, the NASA is devoting some attention to the smaller solid propellant engines that may prove useful in space flight operations. Special attention is being given to spherical solid propellant motors which have proven to be very efficient. Also under active study in the solid rocket area are: techniques for providing variable thrust, engine components (cooled nozzles, segmented thrust chambers, and light-weight structures).

A large effort is directed at the development of the engines required to power the launch vehicles of the manned space flight program. The vehicles involved are the Advanced Saturn and Nova. The engines involved are: the F-1, a 1.5 million pound thrust liquid-oxygen, kerosene engine for the first stages of the Advanced Saturn and Nova; the J-2, a 200,000 pound thrust liquid-oxygen, liquid-hydrogen engine for the second and third stages of Advanced Saturn and the third stage of Nova; and the M-1, a 1.2 million pound thrust liquid-oxygen, liquid-hydrogen engine for the second stage of Nova.

World-wide tracking and data acquisition facilities are depicted on Figure26. These facilities are identified as part of either the deep space net, Mercury net, or satellite net. Also noted are the location of new facilities that would be supported by the fiscal year 1963 budget. Not shown are the optical stations employing Baker-Nunn cameras or a station in Alasks and another one somewhere in the Northeast funded by the Department of Commerce to support the Nimbus Operational System. In actual practice some of the facilities are utilized interchangeably to serve efficiently both NASA and Department of Defense flight missions.

The facilities in foreign countries are generally manned by nationals of that country either independently or with assistance from NASA.

The substantial increase in space flight operations programmed through the 1963 period and beyond, call for expansion of the tracking and data handling capability of many of the stations noted here and dictate the need for new facilities. The increase in station loading is attributable to the operational satellites, the large scientific satellites, the lunar program and the great increase in manned space flight activity.

New facilities are required in Australia and South Africa to increase the data handling capability of the deep space net. At Goldstone, California, a new 240-foot diameter antenna system needed by lunar and planetary missions is being built. A large data acquisition facility for support of satellite programs is planned for installation in the Far East, at a station to be specified.

It can be seen that the National Space Program will require such a broad effort that essentially every one of the scientific disciplines will be needed to contribute knowledge to the program. University scientists can provide one of the key sources of knowledge and can contribute hypotheses, experiments, and research effort. Of even greater importance, the expanded needs for scientific and technical personnel will depend primarily upon an increased student output from the nation's universities. The greatest percentage of increased requirement will fall in the post-graduate and advanced degree categories.

Mr. James E. Webb, the Administrator of the NASA, in recognition of the important role of trained scientists in the National Space Program has said: "It is the desire of the NASA to work with our universities on NASA research programs in a manner that strengthens rather than weakens the university in its traditional role."

To this end the NASA is setting up programs for university cooperation which will include both the support of selected research projects proposed by the universities and a program designed to aid a limited number of students selected by their universities for advanced training in areas important to the National Space Program.

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